CHARACTERIZATION OF THE DIRECT-SMC (D-SMC) PROCESS

Tobias Potyra, Dennis Schmidt, Frank Henning, Peter Elsner

Fraunhofer Institute for Chemical Technology, Joseph-von-Fraunhofer-Str. 7, 76327 Pfinztal (Berghausen), Germany

Abstract

It is a well established fact that Conventional Sheet Molding Compound (SMC) manufacturer/ SMC parts manufacturer uses steps such as resin mixing, blending, sheet manufacture, rolling or festooning, maturation & transportation before actual molding. Often times the sheet manufacturing and the molding operations are in two different locations. While it offers some flexibility in isolating sheet manufacturing from molding, it also leads to challenges in planning, logistics, storage, and maintaining quality through out the process steps.

These factors are some motivation for the industry to develop a process that combines “In-line compounding” with molding operations. The potential for cost savings is large but raw material properties at each step needs calibration and control.

Background and Requirements

This paper is an attempt to further characterize the process with special emphasis on maturation, fiber length distribution & process parameters. Definition of the process window will help predict achievable mechanical properties. This would result in “end-to-end” process evaluation of the Direct SMC process. It will in turn help focus on opportunities & limitations of the process. From materials stand-point, trials covered conventional filler (CaCo3) content varying form 170-200phr, glass fiber content varying between 22 & 38 %wt. & the thickening agent variation.

The process parameters investigated have been screw speed and maturation time. These experiments have been designed with statistical Design of Experiment software. As these trials have been carried out lately, the samples are still being characterized. Due to the editorial deadline the results will not appear in this paper but will be shown in the presentation. Instead a general overview on the Direct SMC process is given in the following.

Introduction

Body panels for the automotive sector requiring Class A appearance are often manufactured from sheet molding compound (SMC) material. The manufacturing process starts with batch mixing of up to a dozen ingredients with the resin in a blend tank. This paste after deareation and proper blending is fed to a continuous compounding line. Using a doctor’s blade process, the paste is spread consistently and continuously on a conveyor of specific width. The in line machinery is also fitted with choppers that chop rovings to set fiber length and drop it on the conveyor in a controlled environment. Going through a series of kneading and compacting rollers, the fiber gets worked in and wetted before the viscosity starts building up. The sheet in rolled or festooned form is maturated in controlled environment for a definite length of time, while dynamic viscosity change takes place. The sheet after maturation is molded into a component using the hot pressing process.

This process could lead to fluctuations in sheet quality and therefore also component quality. It is only possible to determine the quality of the component after some days because of discontinuous process sequence. The process steps of sheet maturation & charge preparation by cutting impose limits on the production volume per line and year. Another disadvantage is the limited flexibility of the process. Changes to a recipe only take effect after several days.

The direct process allows certain restrictions on the processing of SMC to be lifted. Because this is a continuous process in which the raw material is turned into the component within only a few minutes, it is possible to establish a closed loop control in order to guarantee consistent high quality. The resulting reduced scrap rate and lower amount of reworking have a positive effect on component costs. Component costs can also be reduced by the elimination of the stage as well as a shortening of the cycle time. Another advantage of the process is that it offers practically unlimited flexibility in terms of raw material selection and close-to-real-time recipe changes. Styrene emissions also can be reduced because of the use of extrusion compounding machinery.

The modified processing conditions also give rise to different requirements on the viscosity profile during the manufacture of direct SMC, as shown in Figure 1. When SMC is manufactured in the conventional process, it initially has a very low viscosity to enable blending of filler & additives a sheet coating to be achieved and to allow the fibers to be effectively wetted with this. Following this, the objective is to increase the viscosity in the shortest possible time so that the sheet can go on to further processing. The viscosity must be relatively high in order to enable handling of the sheet & fiber carrying with matrix in the molding process. In contrast to this, direct SMC starts with a higher initial viscosity because the fibers are force-wetted during the extrusion step. The viscosity then rises within a few minutes, but reaches a lower ultimate level than in conventional processing. This is sufficient because the material is not cut to shape and is also placed in the mold automatically. Furthermore, the lower viscosity has a beneficial effect on surface quality.

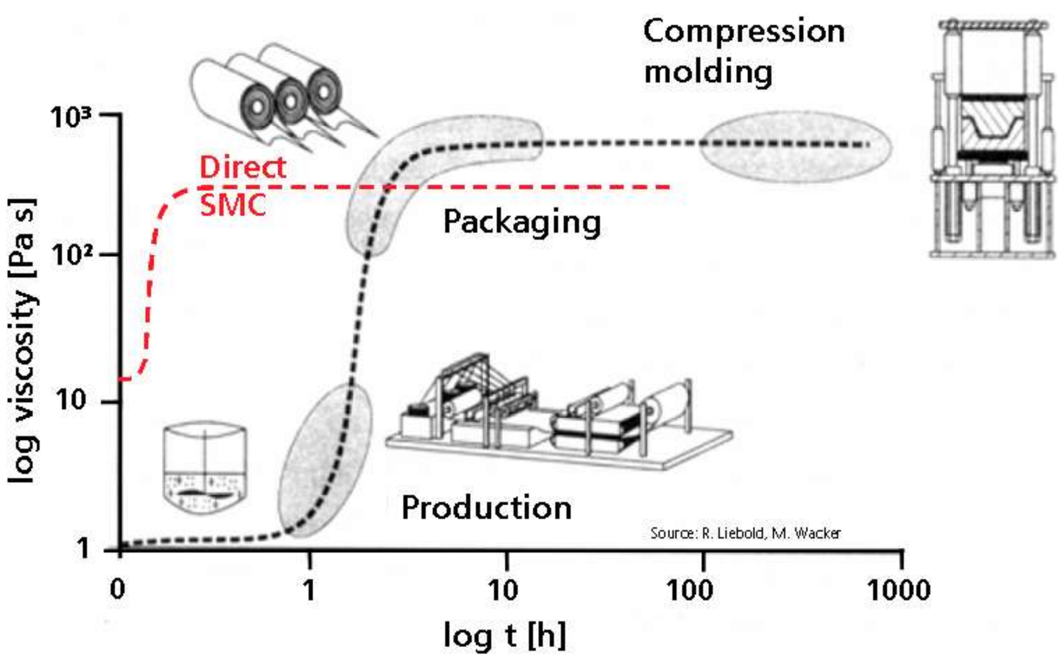


Figure 1: Viscosity profile over time in the classic SMC and direct SMC processes

Description of Machine Technology

The machine technology encompasses the steps of preparing the resin filler mixture, working in the glass fibers and manufacturing the component in an overall process. Figure 2 shows an overview of the processing sequence.

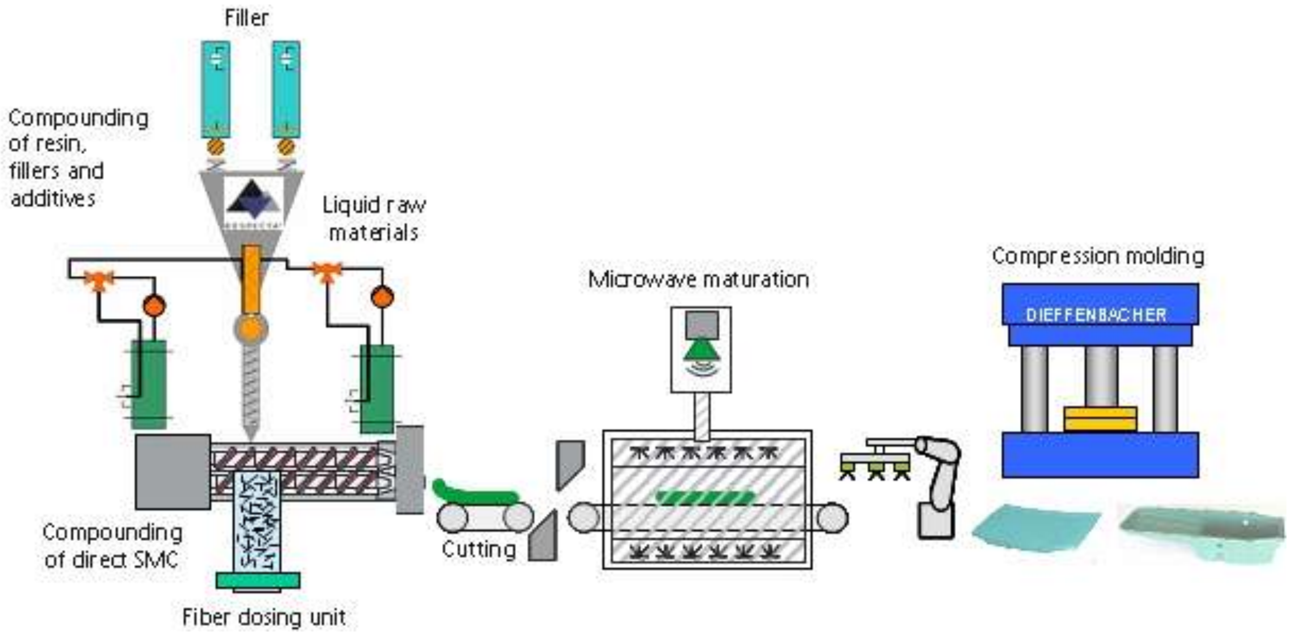


Figure 2: Processing sequence of the direct process for SMC

The liquid components such as resin, LPA, additives and peroxide are gravimetrically fed in a batch mixer. The solid fillers are also gravimetrically fed & batch mixed.. Next the resin paste with all the ingredients except for the reinforcements, is fed into a twin screw extruder, where the reinforcement fibers are worked in. The reinforcement fibers are singled, wetted and dispersed within the extruder. At the output from the extruder, the extruded material is cut to length according to the required component rate and placed on a transport conveyor. The extruded material is heat treated by microwaves in order to set the viscosity. The extruded material is automatically placed in the press and the component is manufactured. The component can be removed from the mold automatically.

Preparation of the Resin Filler Mixture

In the conventional SMC process, the resin/filler paste is prepared using a mixing operation and a blend tank with a blade mixer. This creates a stationary flow profile within the blend tank leading to proper mixing of the raw materials. (See Figure 3).

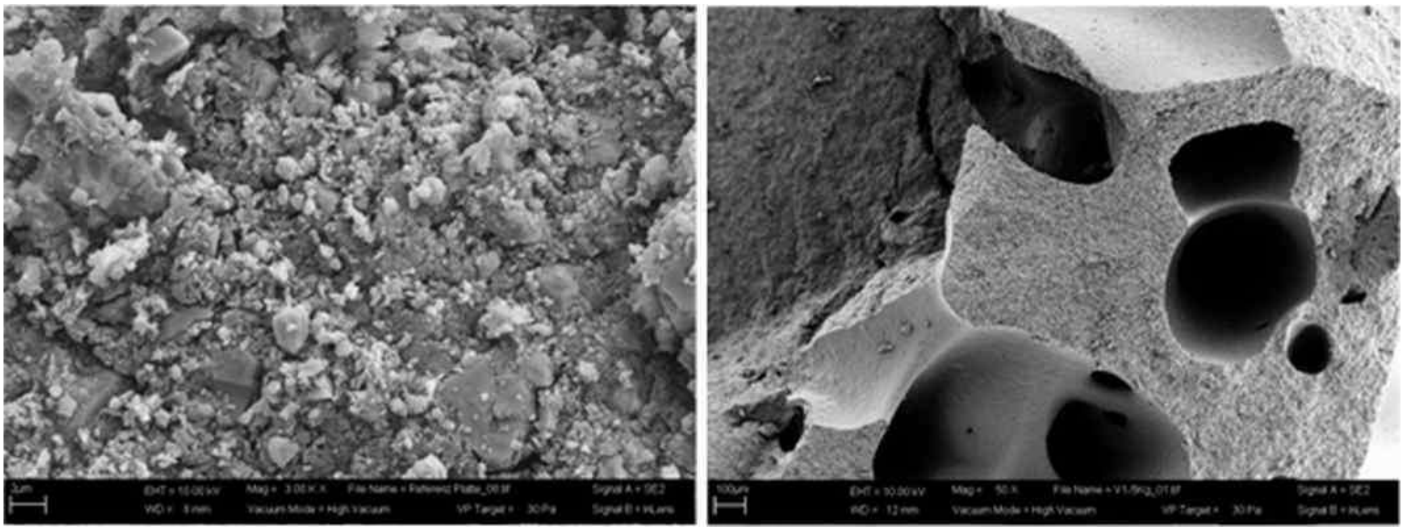


Figure 3: SEM images of resin filler mixture manufactured using a blade mixer

In the direct process, the resin filler mixture is prepared using a continuously mixing extruder. The liquid and solid raw materials are forced through this machine, thereby generating an improved mixing effect. The dispersing effect of the extrusion step can be increased by selecting various screw elements such as kneaders and spiked mixers. The amount of air inclusions are minimized because this is a closed mixing system. In addition, it is possible to establish a vacuum zone.. Figure 4 shows SEM images of a resin filler mixture prepared using an extruder. It is possible to see that the fillers are finely dispersed and very homogeneously distributed. Furthermore, the number of air inclusions is very small.

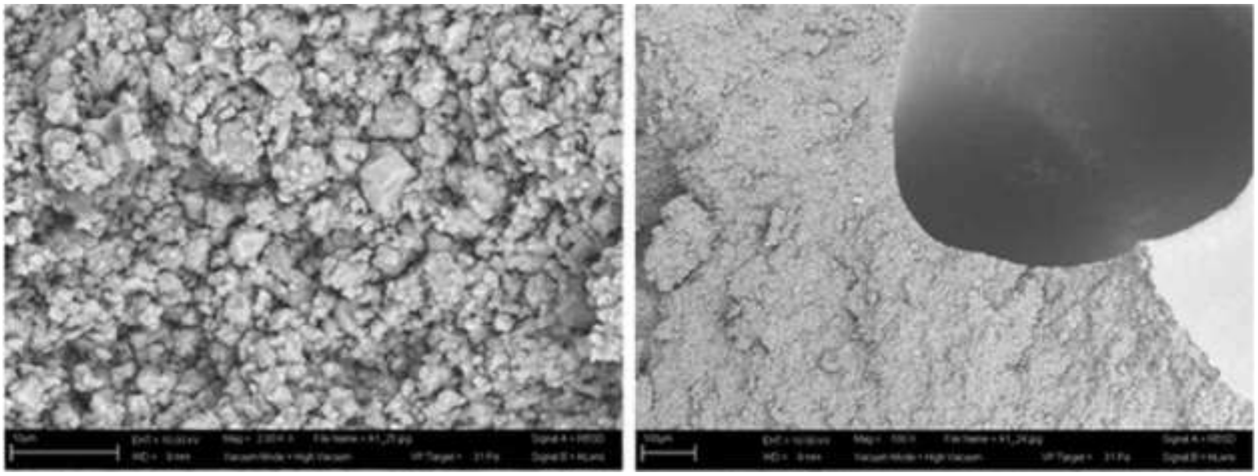


Figure 4: SEM images of a resin filler mixture processed using an extruder

Working in Reinforcement Fibers

Reinforcement fibers can be worked in using various methods. Firstly, the fibers can be fed into the double screw extruder as rovings or, secondly, can be cut in-line.

In the direct fiber feed process, the roving is first passed through a system of rollers as shown in Figure 5. The intention in doing this is to open up the fiber strands evenly so that they are fed in at the same speed across the entire width. The rovings are then fed directly into the extruder and are broken at a defined position using an edge in the cylinder of the extruder. This method of working in is very good for glass fibers because they break at the breaking edge. An advantage of this system is that the fibers are force-wetted. The forced transport of the fibers also means that very high glass concentrations can be achieved. However, not all fibers break under all conditions, so that it is not always possible to achieve a defined maximum fiber length in the material.

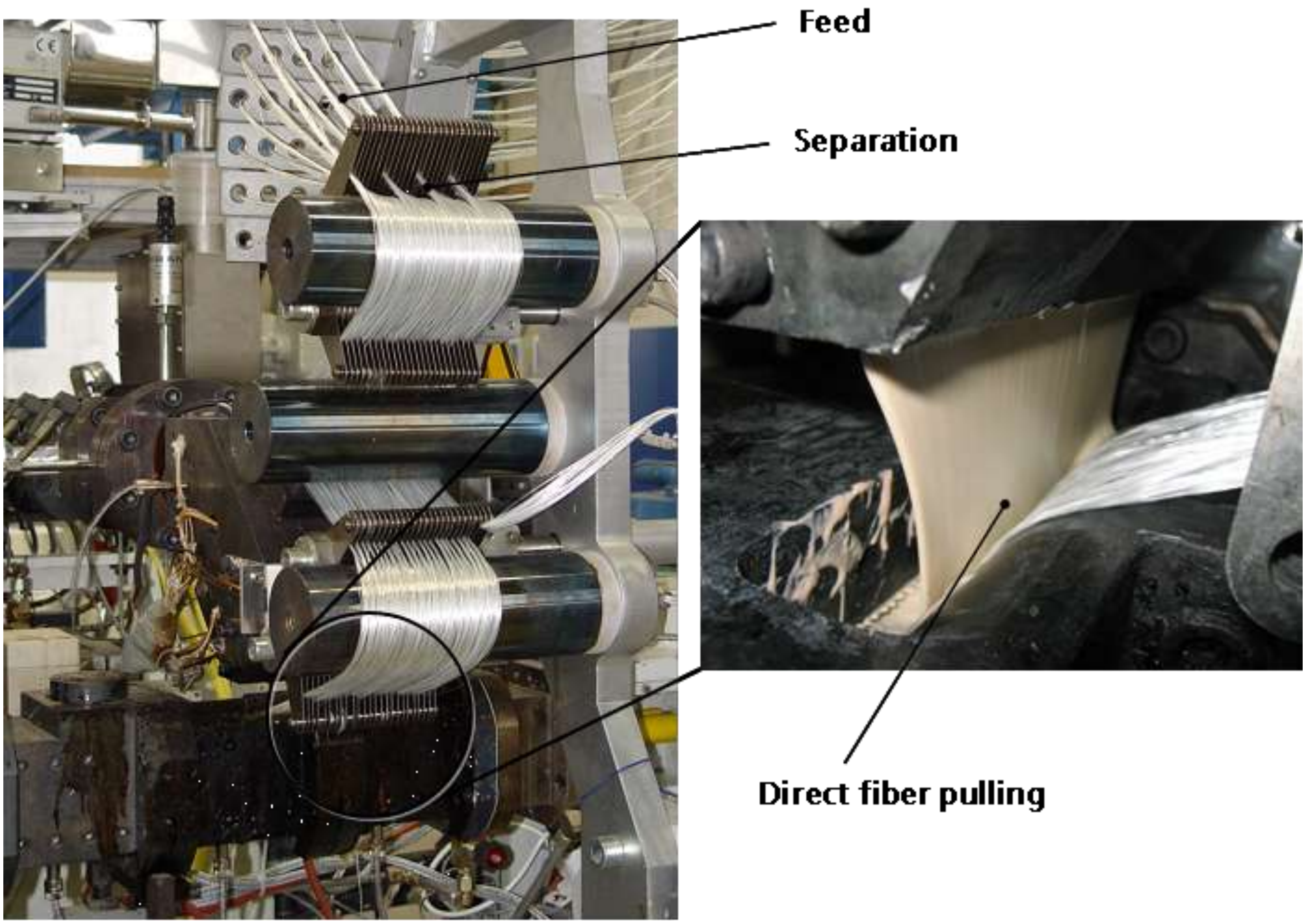


Figure 5: Direct working in of glass fibers in to a twin screw extruder

The second possibility is to cut the fibers in-line and to batch the cut fibers into the extruder, as shown in Figure 6. The fibers are cut using a cutting roller and are supplied to the extruder by a conveyor belt or a chute. The cutting of the fibers means that a defined fiber length is achieved, this being the principal difference from direct fiber technology. In this technology, it is also possible to work in fibers that do not break at the breaking edge in direct technology. In in-line cutting technology, the maximum fiber content depends on the combination of process and material parameters.

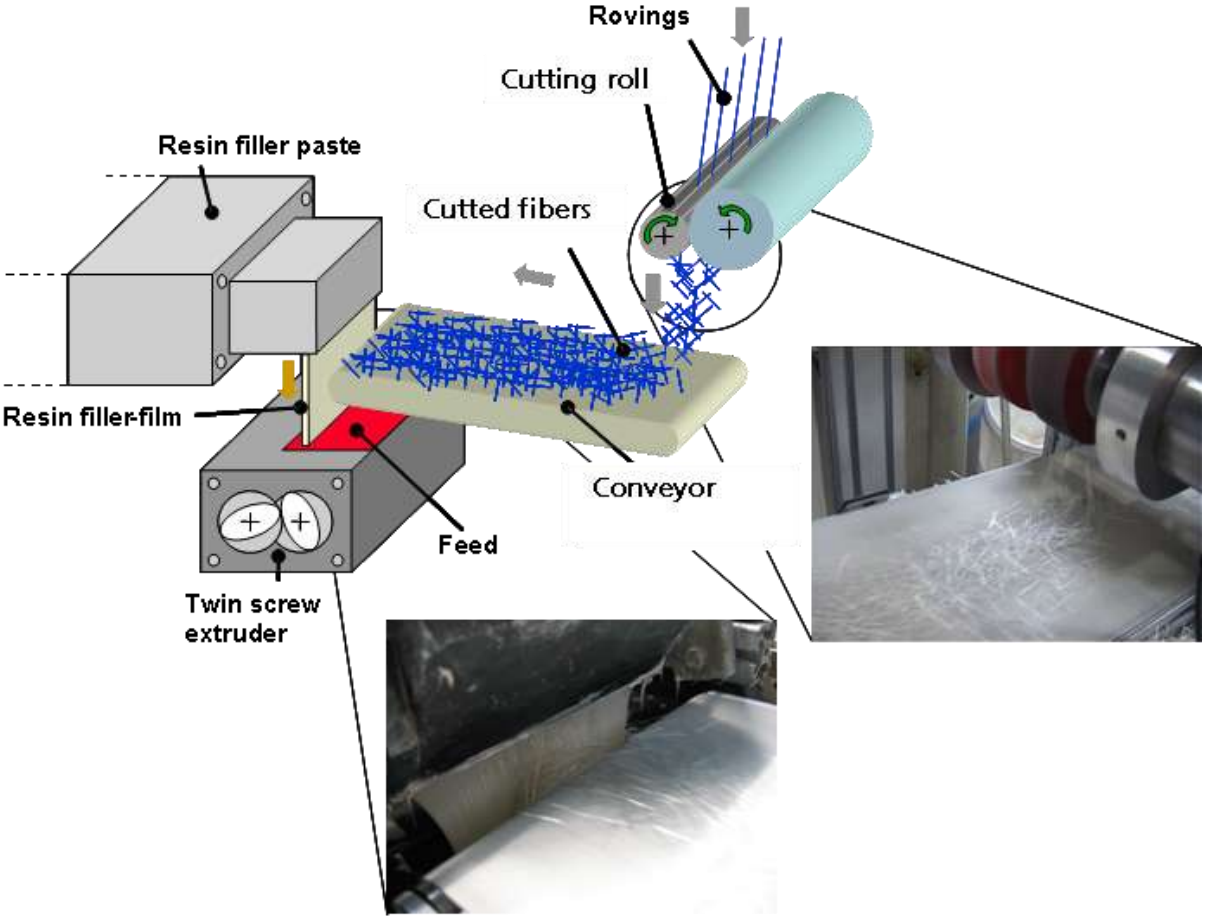
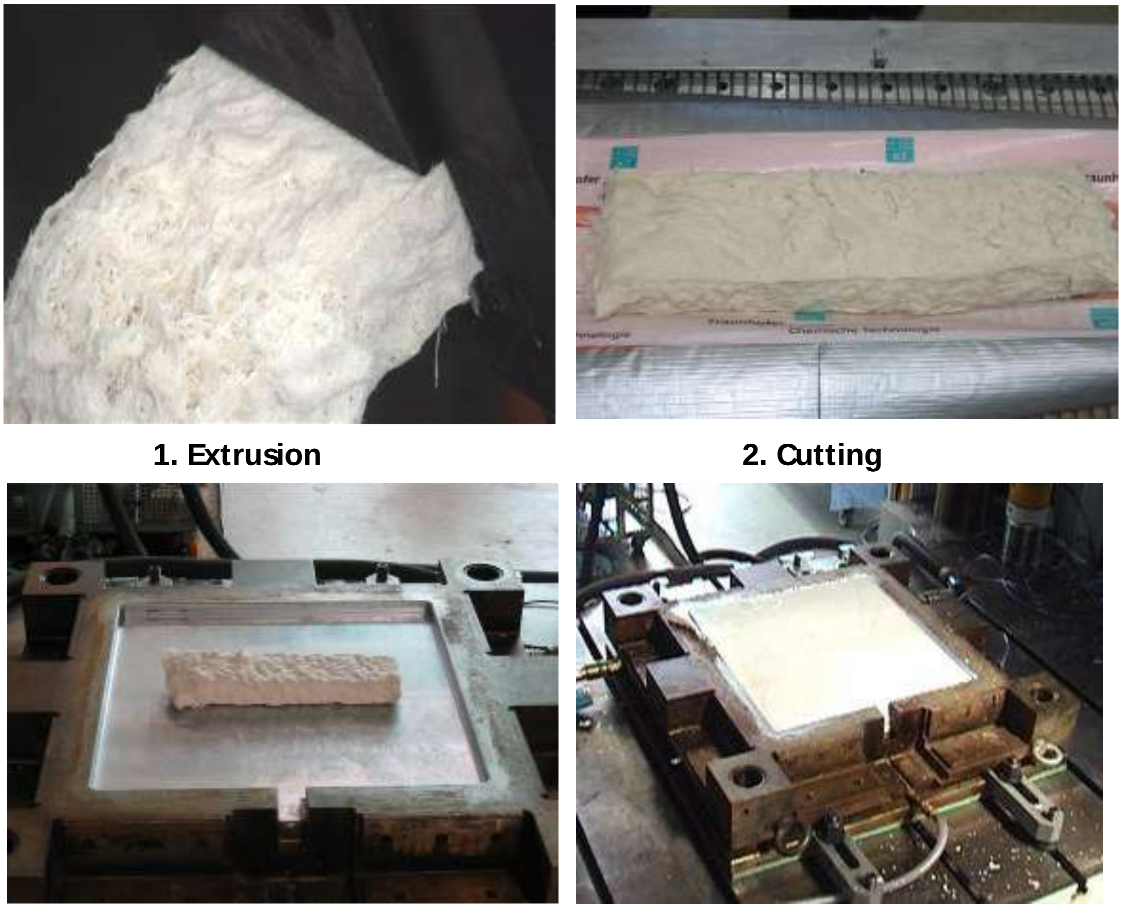


Figure 6: Working in glass fibers with in-line cutting technology

Manufacturing Components

The performance capabilities of the process can be demonstrated during the manufacture of components. Figure 7 shows the individual steps of outputting the extruded material, cutting to length, compression molding and removing a sample panel form the mold.



1. Extrusion **2. Cutting**

3. Compression Molding **4. Demolding**

Figure 7: Steps of outputting the extruded material, cutting to length, compression molding and removing from the mold during the manufacture of an SMC component in the direct process

The resulting mechanical properties will be presented in the ACCE conference session.

Summary and Next Steps

Direct SMC technology represents a process in which SMC is manufactured in a consistent and continuous direct process. The manufacturing time between the raw material and component has been reduced from several days to several minutes. Also it has been possible to show that the filler distribution within the resin additive mixture can be made more homogeneous. Equally, it has been shown that the extrusion step does not have a negative effect on flexural strength. Furthermore, a strand can be extruded that is capable of being handled and can be pressed directly. The various technologies for incorporating fibers means that it is possible to select the fiber material flexibly and adapt it to the requirements on the component.

The next steps will be characterizing the process and the material by systematical statistic approach.

Acknowledgements

The authors are particularly grateful to Projektträger Jülich (PTJ) as well as the German Federal Ministry for Education and Research who provided public funding (funding code: 03X3000) to enable this joint project to be carried out. In addition, the authors are grateful to the project partners BYK Chemie, Johns Manville, M-Base, Polytec Composites Germany, Reichhold, Respecta and Volkswagen.